

FIBER-OPTIC SENSOR DEVICE AND METHOD

BACKGROUND OF THE INVENTION

The present invention relates generally to sensor devices and methods for monitoring conditions in a surrounding medium, and is particularly concerned with fiber-optic sensor devices.

It is often important to be able to monitor various properties in gaseous and liquid media. Some properties which can be critical are humidity, contaminant levels, pollutant levels, battery solution composition, and so on.

Current means of measuring air humidity involve either a special polymer sensor head whose capacitance is dependent on the amount of moisture it absorbs, or a dew point meter. Both have adequate accuracy, but are slow in response time and expensive to manufacture.

Some proposals have been made in the past for fiber-optic sensor devices which detect changes in the refractive index of a surrounding medium, for various applications. A conventional optical fiber has a light transmitting, optical fiber core of glass, an outer cladding of different refractive index from the core to prevent optical loss from the core, and an outer protective layer, usually of plastic. In U.S. Pat. Nos. 4,851,817 and 5,005,005 of Brossia et al., an optical fiber has portions of both the outer protective layer and the cladding layer removed, exposing the core. The exposed core is provided with striations by abrading or sanding it with a piece of sandpaper or the like. The sensor surface irregularities cause light to refract out of the fiber and into the surrounding medium, with the amount of light lost being dependent on the refractive index of the surrounding medium. A photodetector senses the amount of light transmitted along the fiber past the sensor portion. Changes in the amount of light transmitted provide an indication of changes in the surrounding medium. Brossia describes possible uses for this sensor device in providing an indication of icing conditions on aircraft, and also for soil moisture detection, detection of leakage from underground storage tanks, and for fluid level detection.

One problem with this sensor device is that the optical loss through a length of bare fiber core is very high. In fact, 90% or more of the light may be lost under such conditions. Thus, this device is only capable of detecting gross changes in the refractive index of a surrounding medium. This sensor device will not be sensitive enough to detect small changes in air humidity, for example.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a new and improved fiber-optic sensor device.

According to the present invention, a sensor device is provided which comprises an optical fiber having a core, a cladding layer surrounding the core, and an outer protective layer, at least a portion of the outer protective layer being removed to expose a portion of the cladding layer, and the exposed portion of the cladding layer being roughened to provide scratches which extend through at least part of the thickness of the cladding layer. One end of the fiber is connected to a suitable light source, while the opposite end is connected to a detector for detecting the amount of light transmitted through the fiber and producing an output signal proportional to the amount of light transmitted.

The roughened, exposed portion of the cladding layer is placed in a medium to be monitored. The light propagating

through the fiber will suffer heightened scattering loss at its surface in the sensor region where the cladding is roughened and exposed. The amount of light lost will depend very strongly on the refractive index of the medium into which the fiber is immersed. In dry air, the scattering loss will be the highest, while high humidity air, which has a larger refractive index than dry air, will produce decreased scattering loss and more light transmitted through the fiber. Thus, the transmission loss is directly dependent on the humidity of the surrounding air, and an accurate measurement of humidity can be made.

The advantage of this technique over optical fiber sensors where the entire cladding layer is removed and the fiber surface is roughened is that less light will be lost, and thus a larger, more accurate signal is produced. The unaffected part of the cladding around the scratches will still act to retain light in the core, so that light can only escape through the roughened regions. This produces a much more accurate and sensitive device.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the following detailed description of a preferred embodiment of the invention, taken in conjunction with the accompanying drawings, in which like reference numerals refer to like parts, and in which:

FIG. 1 is a perspective view of part of an optical fiber sensor element according to a preferred embodiment of the invention, with a portion of the cladding layer cut away to illustrate the surface roughening more clearly;

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1; and

FIG. 3 illustrates one example of a sensor system incorporating the optical fiber sensor element.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 1 and 2 of the drawings illustrate a fiber-optic sensor device 10 according to a preferred embodiment of the present invention, while FIG. 3 illustrates a possible sensor system for sensing changes in the refractive index of a surrounding medium utilizing the sensor device of FIGS. 1 and 2.

The sensor device 10 is made using a conventional optical fiber having a light transmitting fiber core 12 of fused silica or the like, a cladding layer 14 for preventing or restricting transmission of light radially out of the core, and a protective outer or buffer layer 16, which is usually of plastic material. It will be understood that this invention may be applied to any type of optical fiber and is not limited to fused silica glass fibers. The sensor element 10 has at least a portion of the outer buffer layer 16 stripped from the cladding layer and core, so that the outer surface 18 of the cladding layer is exposed along the length of the stripped portion. The outer layer 16 may be stripped using a standard optical fiber stripper, such as Model F-STR-125 of Newport Corp, or using a razor blade or the like. Although only a portion of the outer buffer layer is removed in the embodiment of FIGS. 1, 2 and 3, in some cases the buffer layer 16 may be removed along the entire length of the fiber. The length of the exposed portion 32 of the cladding layer is determined based on the desired sensitivity of the sensor, as discussed in more detail below.

The exposed surface 18 of the cladding layer is roughened by grinding with a selected grinding powder to produce a